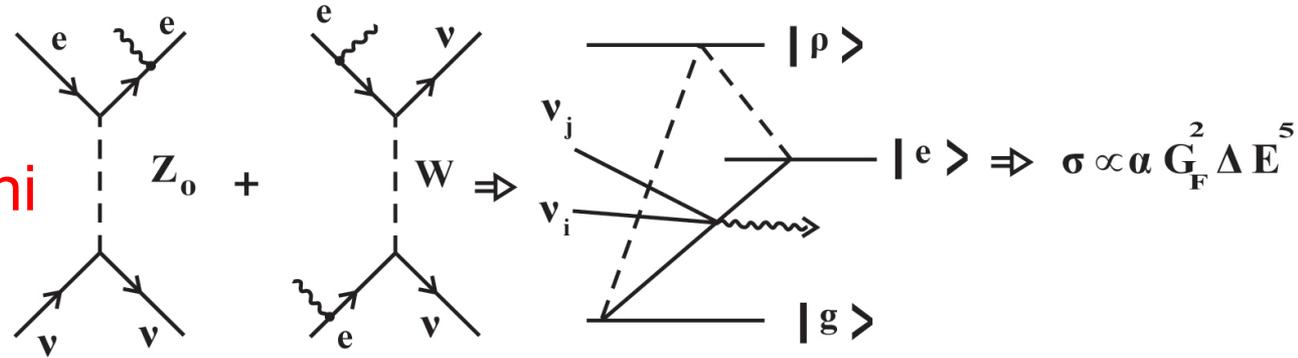


Low Energy Particle Detector: Laser Induced **DORELAS**

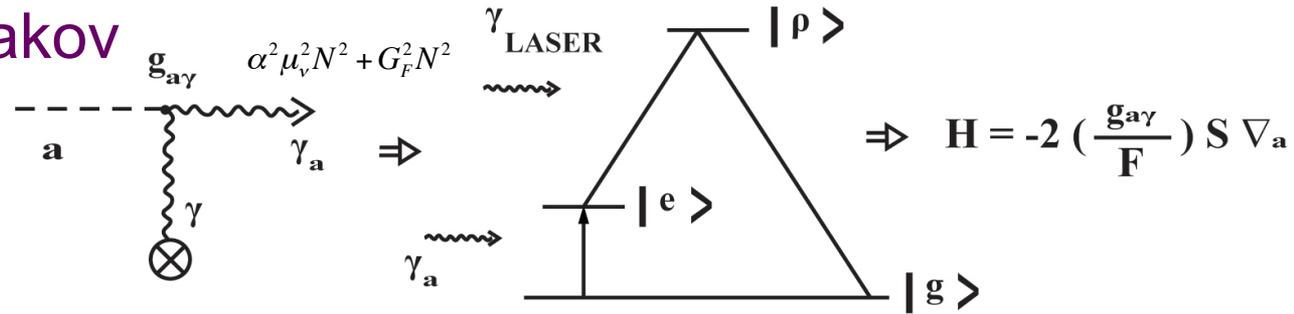
- **Fisica vs Rivelatori a Bassa Soglia di Energia**
- **Da KeV a eV Breve sguardo d'insieme e prospettive**
- **Pompaggio Laser su “ Mezzo Attivo “ : RIVELATORE**
- **Progetto di Ricerca**
- **Richieste :Finanziarie ,Sezione, F.T.E.**

Processi Fisici e Basse Soglie di Energia

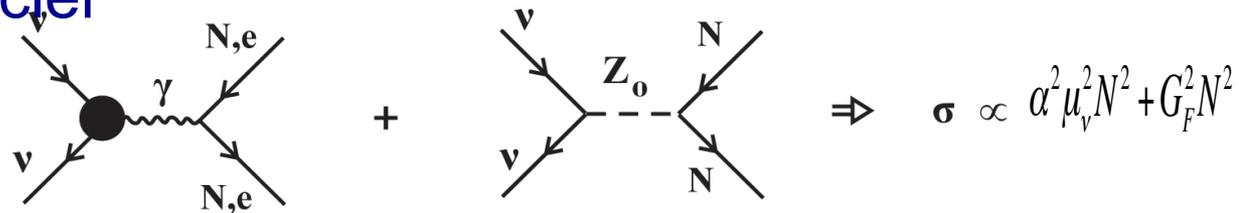
Emissione a 2 neutrini



Assione-Effetto Primakov



Scattering coerente di neutrino
Via EM e Debole su Nuclei



Processi Fisici e Basse Soglie di Energia

- **Neutrino Scattering Coerente via Z_0 su Nuclei** $E_r = E_\nu^2 / M_N$
(Neutrini Solari o da Reattore rilasciano 10 – 100 eV)
- **Neutrino Momento Magnetico su Nucleo** $\sigma \propto Z_N^2 \mu_\nu^2 / E_{R.N}$
- **Materia Oscura : Assioni e WIMPS Ridurre Energia Soglia**
- **Electron Capture Enhancement under Atom-Laser Illumination**
- **Sezione d'urto differenziale neutrini Vs elettroni (nuclei)**
Forward Scattering dei Neutrini e Campo Magnetico Efficace
Violazione di CP attraverso esperimenti di EDM e Assioni
Accoppiamenti Gravito-Magnetici su Particelle Elementari

Macroscopic T Nonconservation: Prospects for a New Experiment

William Bialek, John Moody, and Frank Wilczek

Institute for Theoretical Physics, University of California, Santa Barbara, Santa Barbara, California 93106

(Received 19 December 1985)

Breakdown of time-reversal invariance can be detected in macroscopic samples as a magnetic alignment along an electric field. We show that both fundamental and practical limits to the detection of this effect in paramagnets correspond to measurement of electron electric dipole moments down to $d_e \sim 10^{-28} e \cdot \text{cm}$ on 50-g quantities of EuS near its Curie point; this compares to the current limit of $d_e \leq 10^{-24} e \cdot \text{cm}$. Strategies for still greater sensitivity are outlined.

Search for an Axionlike Spin Coupling Using a Paramagnetic Salt with a dc SQUID

Wei-Tou Ni, Sheau-shi Pan, Hsien-Chi Yeh, Li-Shing Hou, and Juling Wan

Center for Gravitation and Cosmology, Department of Physics, National Tsing Hua University,

Hsinchu, Taiwan 30043, Republic of China

(Received 11 June 1998)

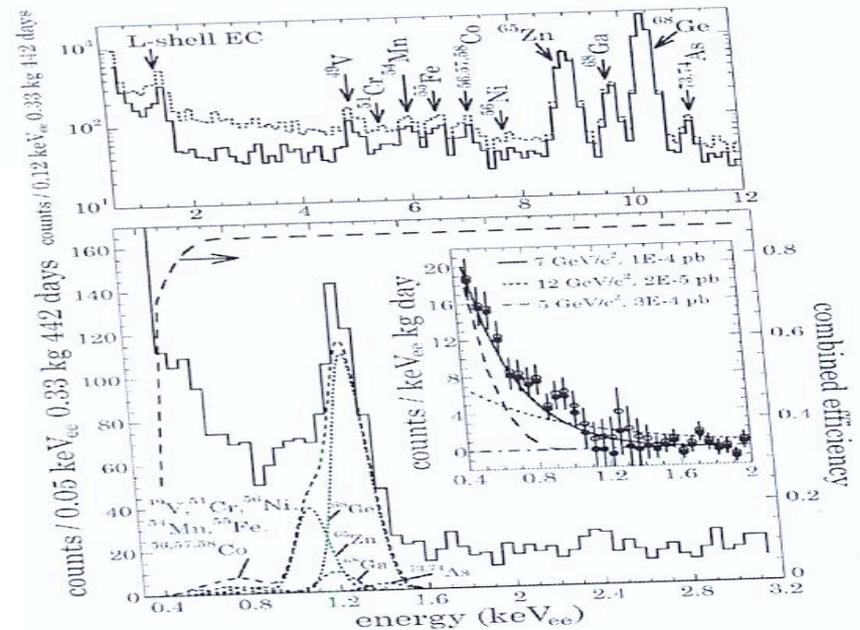
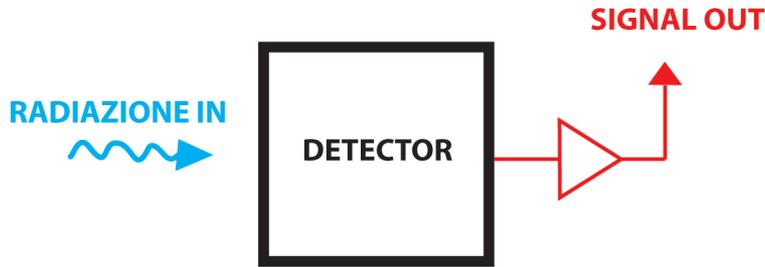
We use a paramagnetic salt TbF_3 with a dc SQUID to search for a possible axionlike $\boldsymbol{\sigma} \cdot \mathbf{r}$ interaction of a rotating copper mass with the salt. We set new limits on the axion coupling constant $g_s g_p / \hbar c$ and the finite-range Leitner–Okubo–Hari Dass coupling constant A . Our limit for range λ at 30 mm is 2 orders of magnitude better than previous results. For $\lambda > 30$ mm, $g_s g_p / \hbar c$ is $(0.14 \pm 0.67) \times 10^{-28}$, and A is less than 10. The outlook for further improvement is discussed.

[S0031-9007(99)08656-1]

Stato Attuale Rivelatori Basse Soglie

$$\text{Segnale} \propto E_{\text{rilasciata}} / w_{\text{detector}} \quad (\text{Fano Factor, Quenching Factor, ...})$$

$$W \approx 2,5 E_{\text{gap}} \quad \text{Shockley}$$



Scintillatori : Kev (40 ph/KeV) Q.F. elevato alle basse energie , F.F. alto

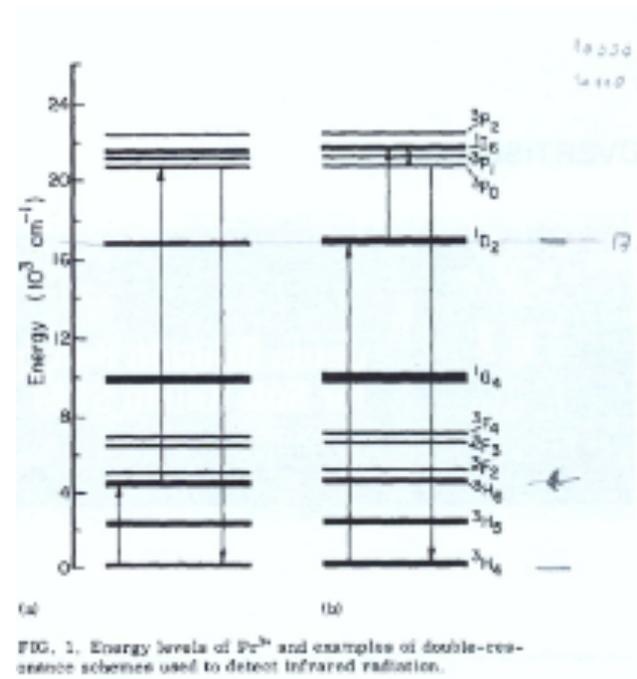
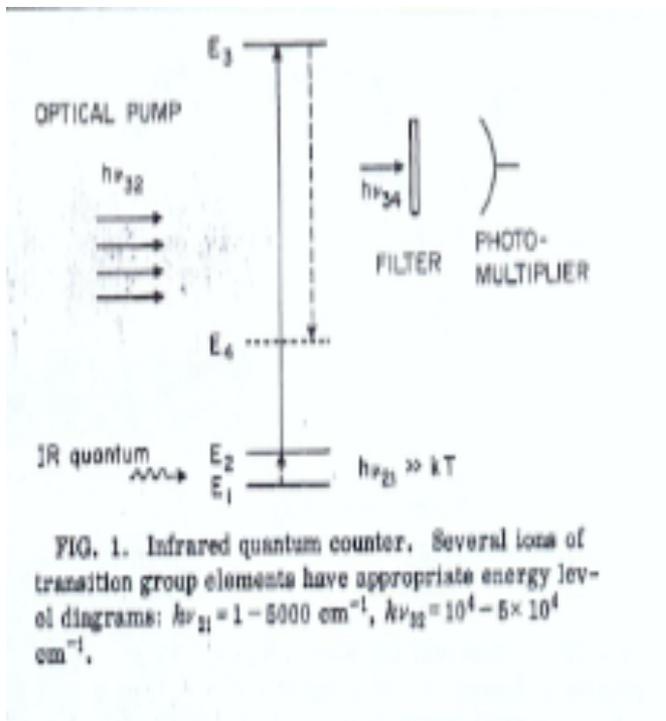
Semiconduttori : 400 eV (1 e/h /3,6 eV Si , 100 elettroni rumore a bassa Capacita')

Bolometri : 100 eV (Capacita termica totale, basse soglie piccole masse e milliKelvin)

Infrared Quantum Counter Idea

Bloembergen (Nobel Prize) suggested to detect IR photons with large Q.E.

where No Phototube are available at IR wavelenght (PRL '59)



Actual Quantum Efficiency for 10 micron IR photons almost at 100% level

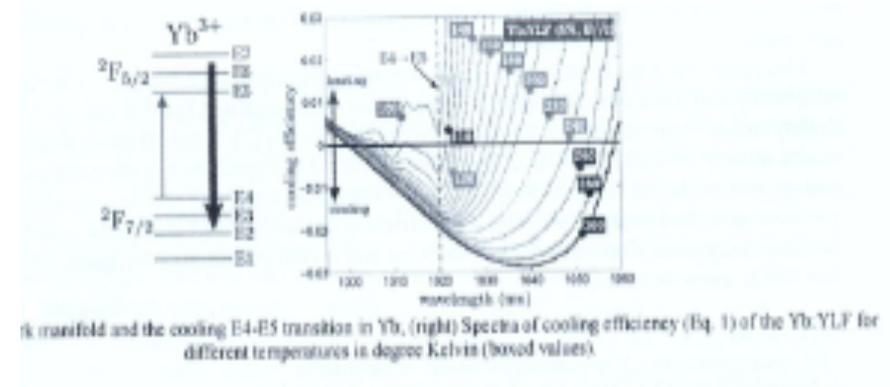
Laser Cooling of Solid

Densita' Fononica Cristallo $KT = 25 \text{ meV}$

Promuove stati eccitati a bassa energia

I quali sono portati su stati eccitati elevati

Da laser tunato su opportune transizioni.



Fotone Fluorescenza emesso = Fotone laser + Fonone Reticolo

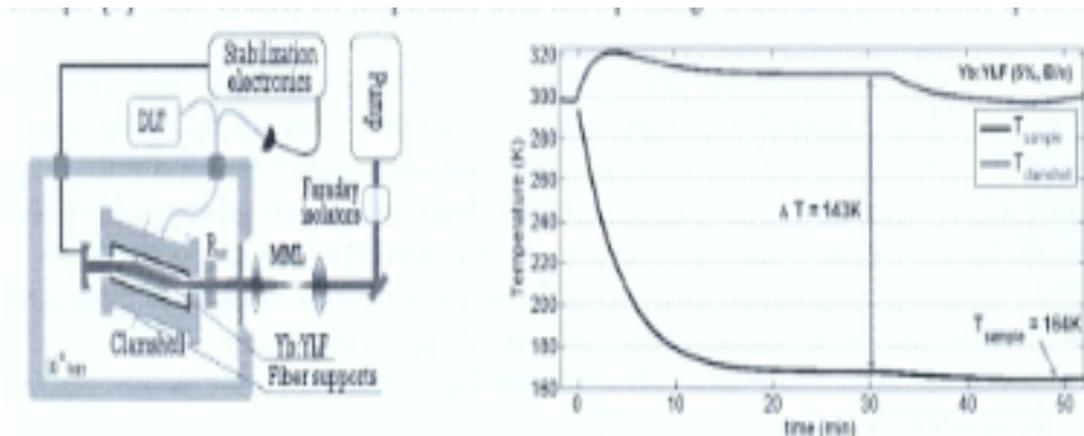
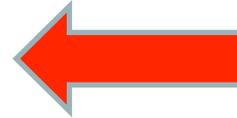


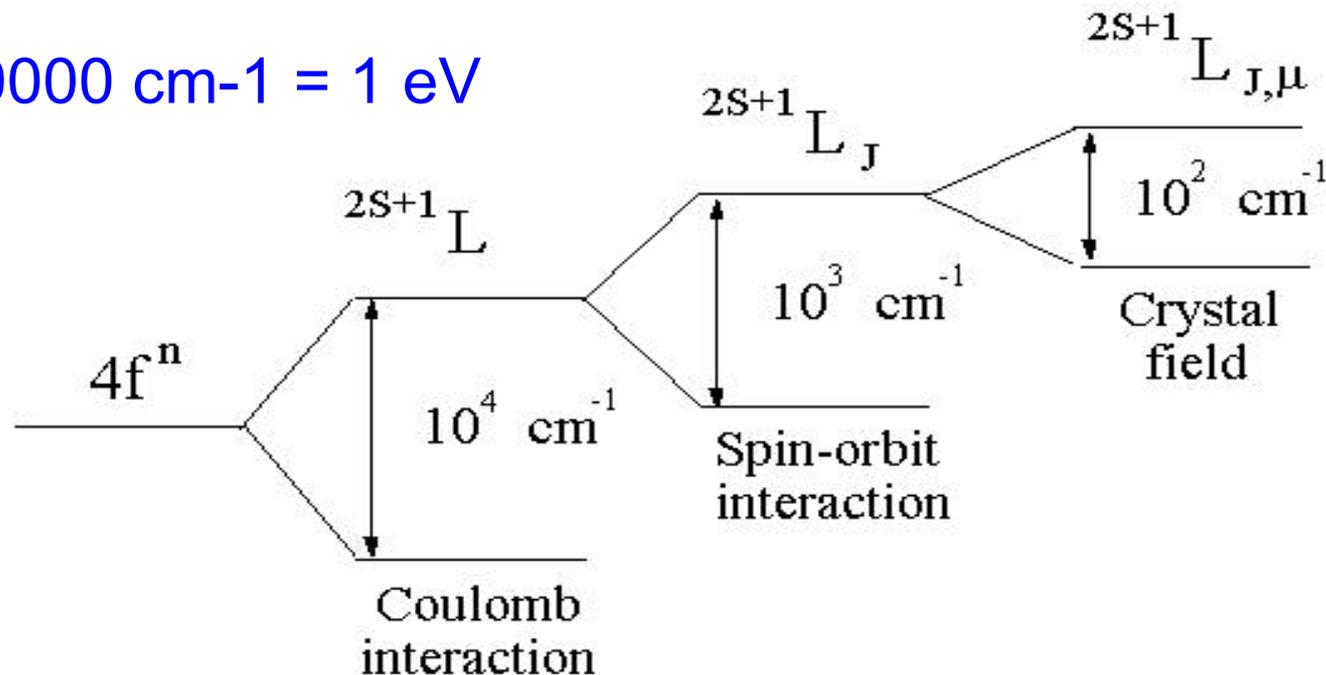
Fig 2: (left) Schematic of experimental setup, (right) Experimental demonstration of feasibility of an optical cryocooler.

Materials Optical Phonon Energy

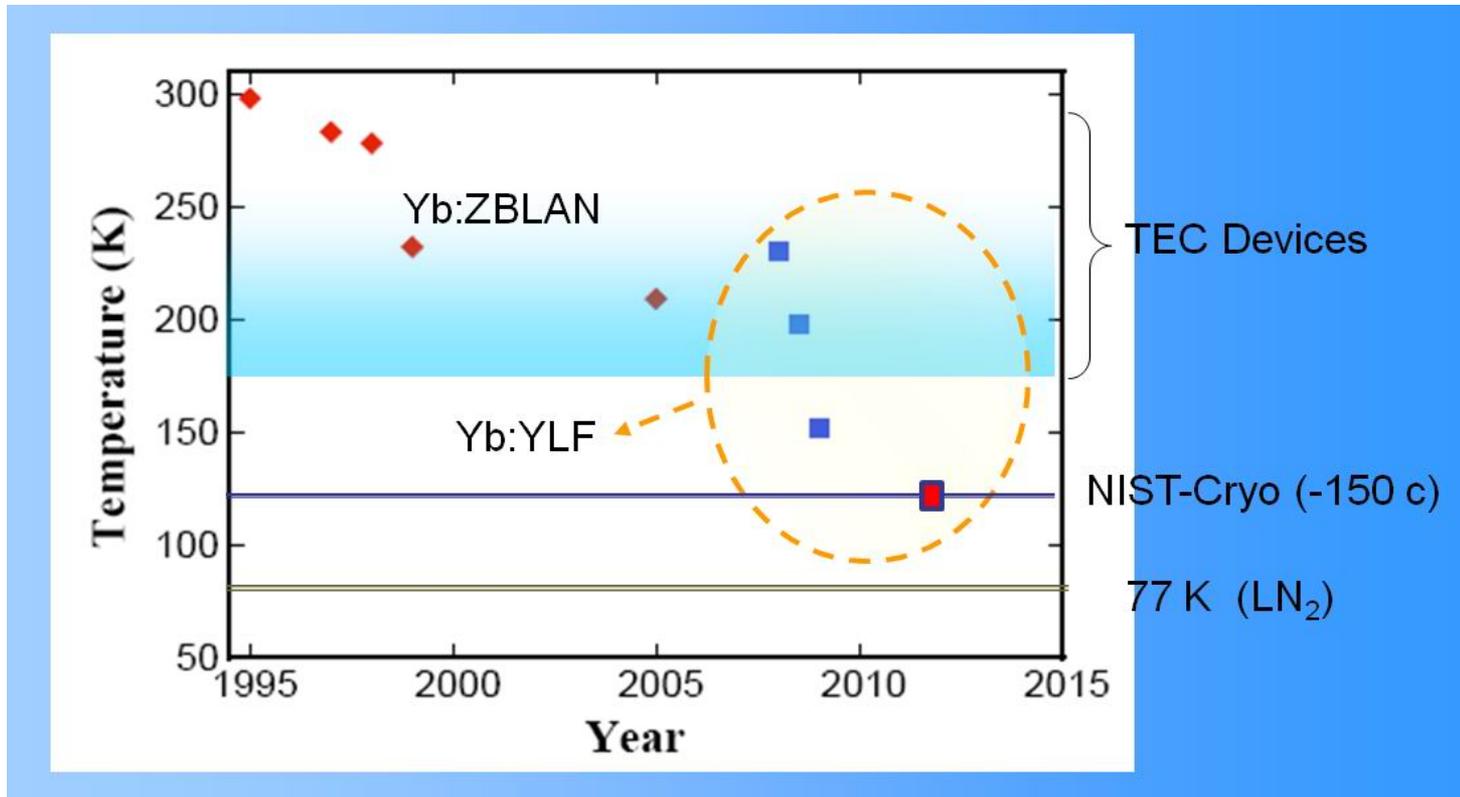
- Oxide crystal : $\sim 800 \text{ cm}^{-1}$
- Fluoride Crystal: $\sim 400 \text{ cm}^{-1}$
- Chloride Crystal: $\sim 300 \text{ cm}^{-1}$



$10000 \text{ cm}^{-1} = 1 \text{ eV}$



Optical Cooling

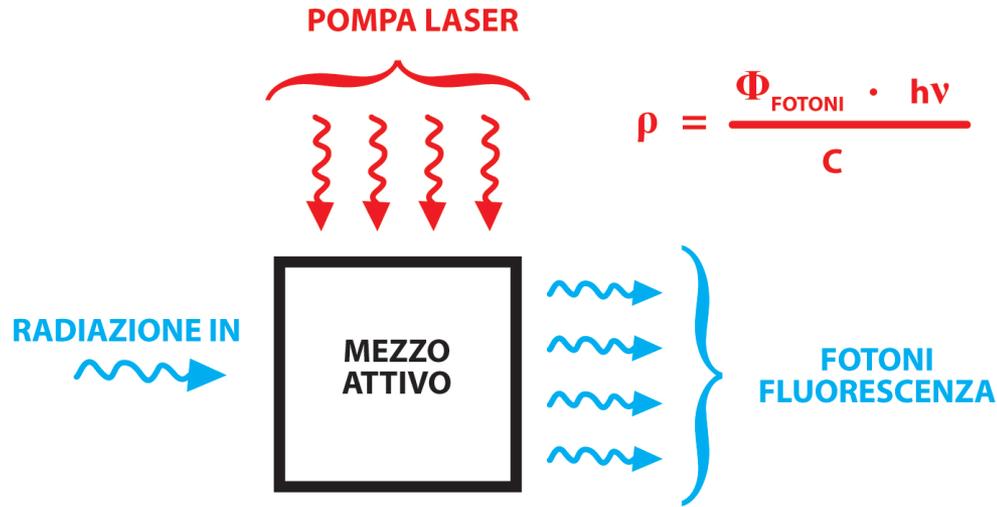


Now the lowest temperature: 119+₋₁ K (~ -154 C)!

- Opt. Letters **38** (2013) 1588-1590
- Nature Photonics **4** (2010) 161-164
- Opt. Express **18** (2010) 18061-18066

$$\alpha_{\beta} = \sim 10^{-4} \text{ cm}^{-1}$$

A New Detector Approach for Low Energy Release

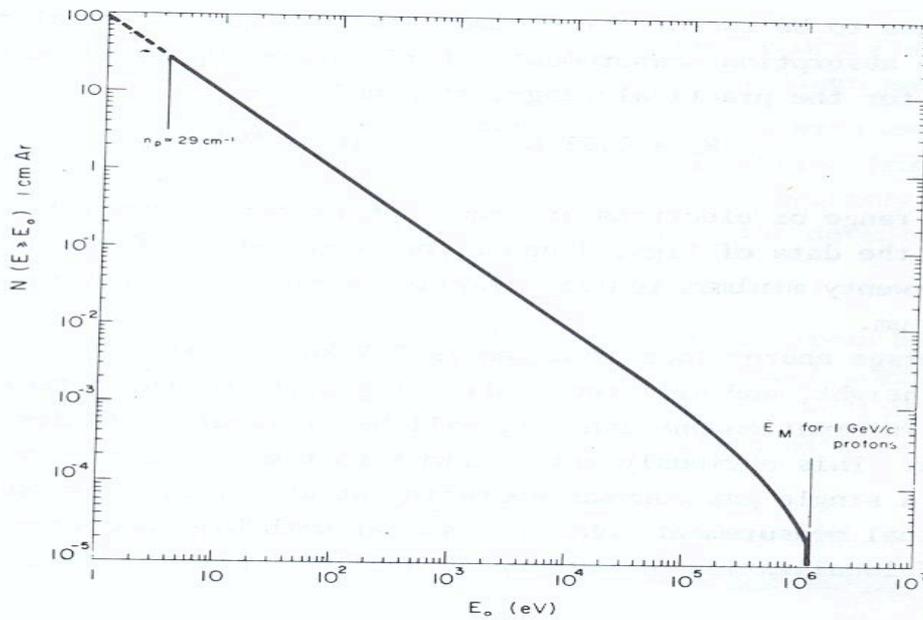


Radiazione in Attraverso dE/dx Promuove atomi su stati eccitati

Maggior probabilita' $P(e) = 1/E^2$ su stati di bassa energia

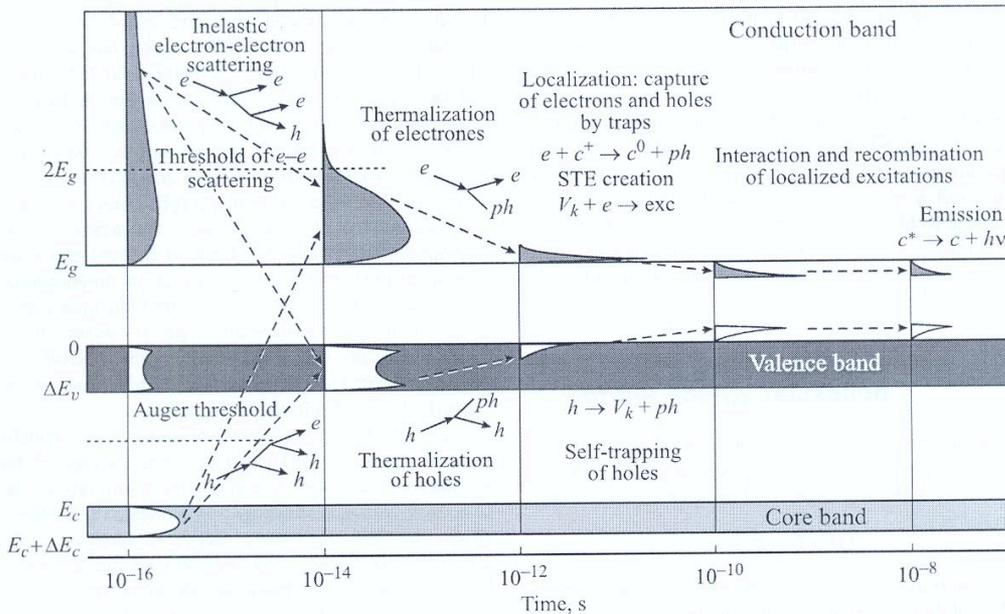
Campo Cristallino Mezzo Attivo rimuove la degenerazione sullo stato fondamentale

Generando primi stati eccitati a livelli di 10 meV



$$P(E)dE = \frac{K}{\beta^2} \frac{Z}{A} \frac{x}{E^2} dE = W \frac{dE}{E^2} .$$

Fig. 4



Scattering elettronici su Fononi Ottici

Figure 1. General scheme of relaxation of electronic excitations in an insulating material.

Detection and Imaging of He₂ Molecules in Superfluid Helium

W. G. Rellergert, S. B. Cahn, A. Garvan, J. C. Hanson, W. H. Lippincott, J. A. Nikkel, and D. N. McKinsey*

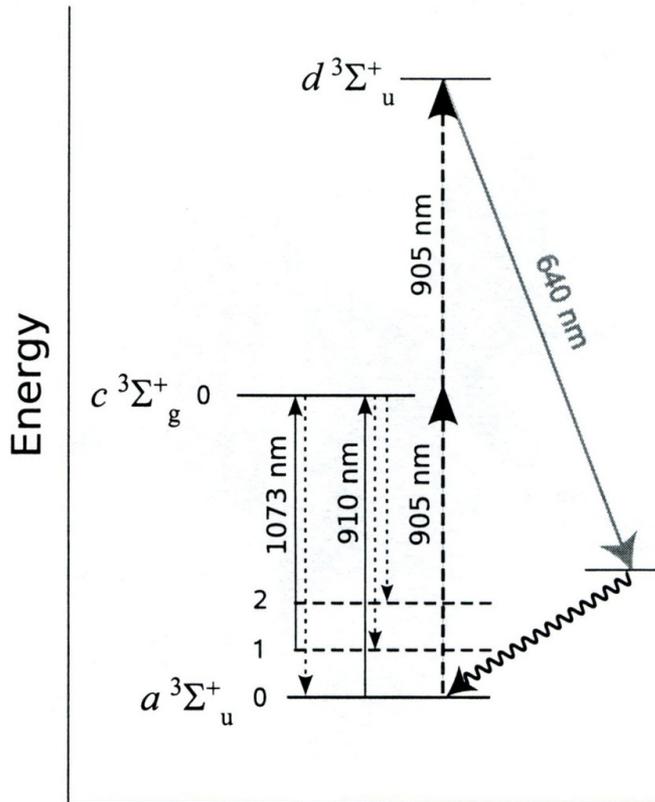
Department of Physics, Yale University, New Haven, Connecticut 06520, USA

(Received 10 September 2007; revised manuscript received 15 November 2007; published 15 January 2008)

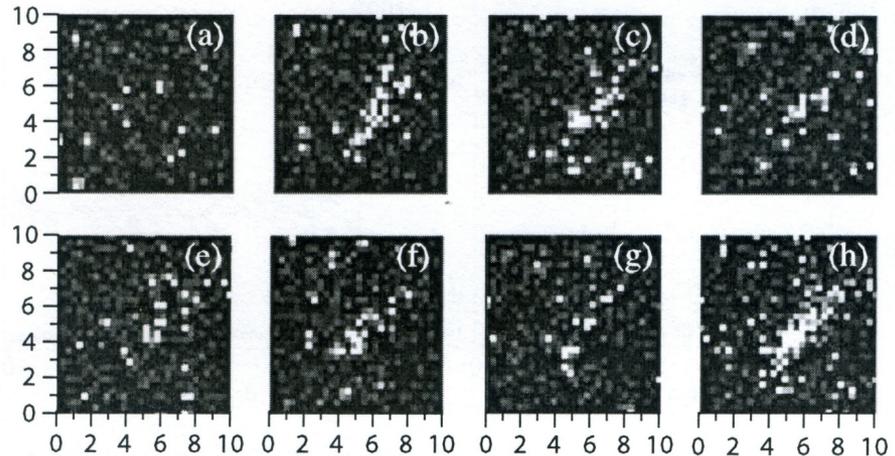
We present data that show a cycling transition can be used to detect and image metastable He₂ triplet molecules in superfluid helium. We demonstrate that limitations on the cycling efficiency due to the vibrational structure of the molecule can be mitigated by the use of repumping lasers. Images of the molecules obtained using the method are also shown. This technique gives rise to a new kind of ionizing radiation detector. The use of He₂ triplet molecules as tracer particles in the superfluid promises to be a powerful tool for visualization of both quantum and classical turbulence in liquid helium.

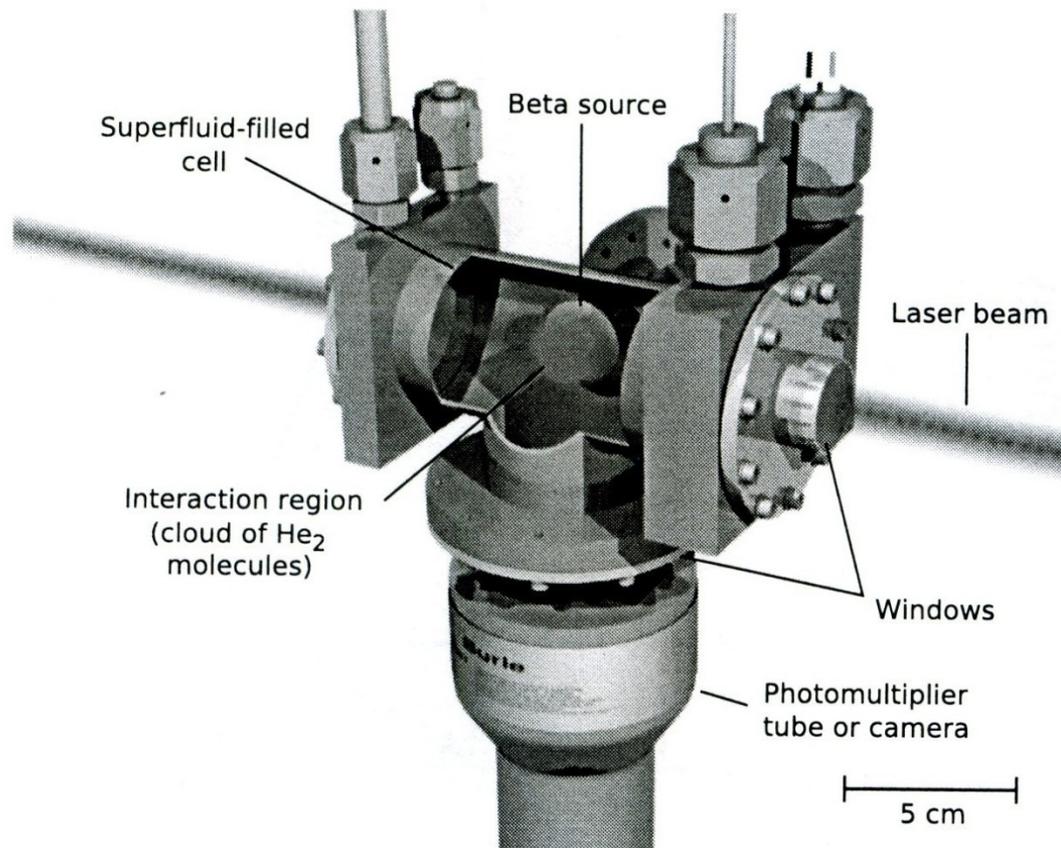
DOI: 10.1103/PhysRevLett.100.025301

PACS numbers: 67.25.D-, 29.40.Gx, 67.25.dk

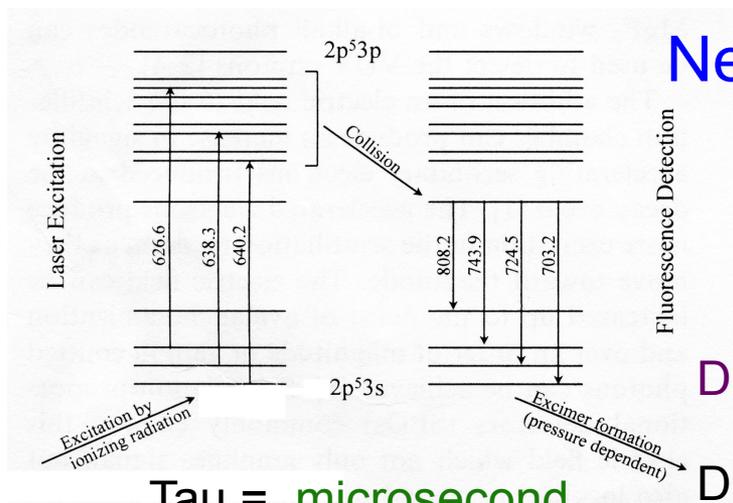


Tracce Elettrone Compton in Elio Liquido CCD





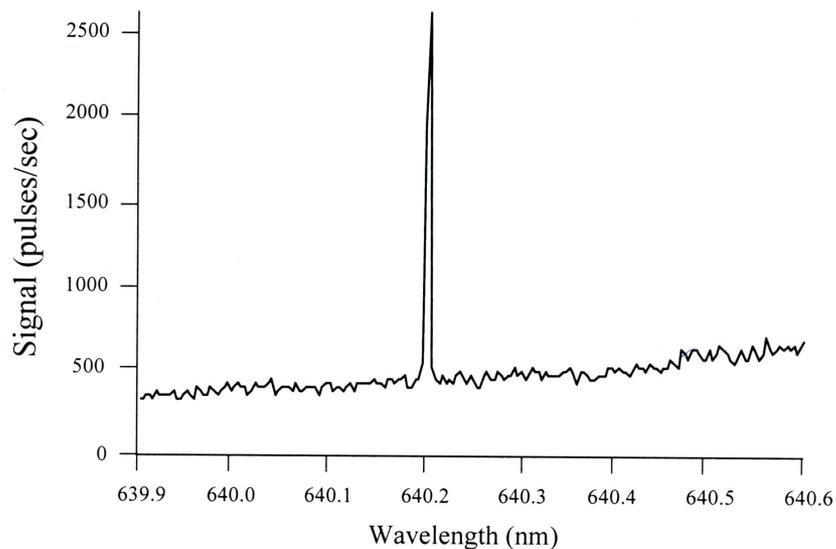
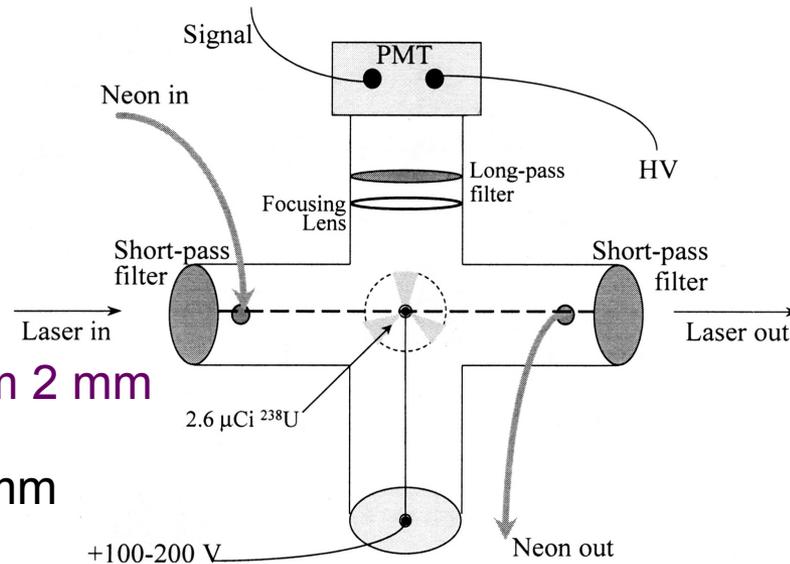
Laser Based Scintillation: Alfa Detection NIM 2002



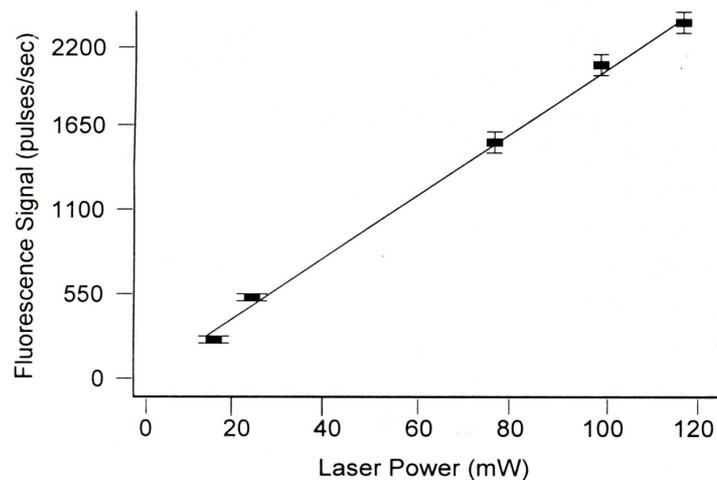
Tau = microsecond

DE/Dx = 10 KeV/mm

Diam. Laser beam 2 mm



Transizione saturata a 80 W/cm²





US 20130032722A1

(19) **United States**

(12) **Patent Application Publication**
Szupryczynski et al.

(10) **Pub. No.: US 2013/0032722 A1**

(43) **Pub. Date: Feb. 7, 2013**

(54) **RADIATION DETECTION WITH OPTICAL AMPLIFICATION**

(75) Inventors: **Piotr Szupryczynski**, Knoxville, TN (US); **Matthias J. Schmand**, Lenoir City, TN (US); **Mark S. Andreaco**, Knoxville, TN (US); **James L. Corbell**, Knoxville, TN (US)

(73) Assignee: **SIEMENS MEDICAL SOLUTIONS USA, INC.**, Malvern, PA (US)

(21) Appl. No.: **13/426,667**

(22) Filed: **Mar. 22, 2012**

Related U.S. Application Data

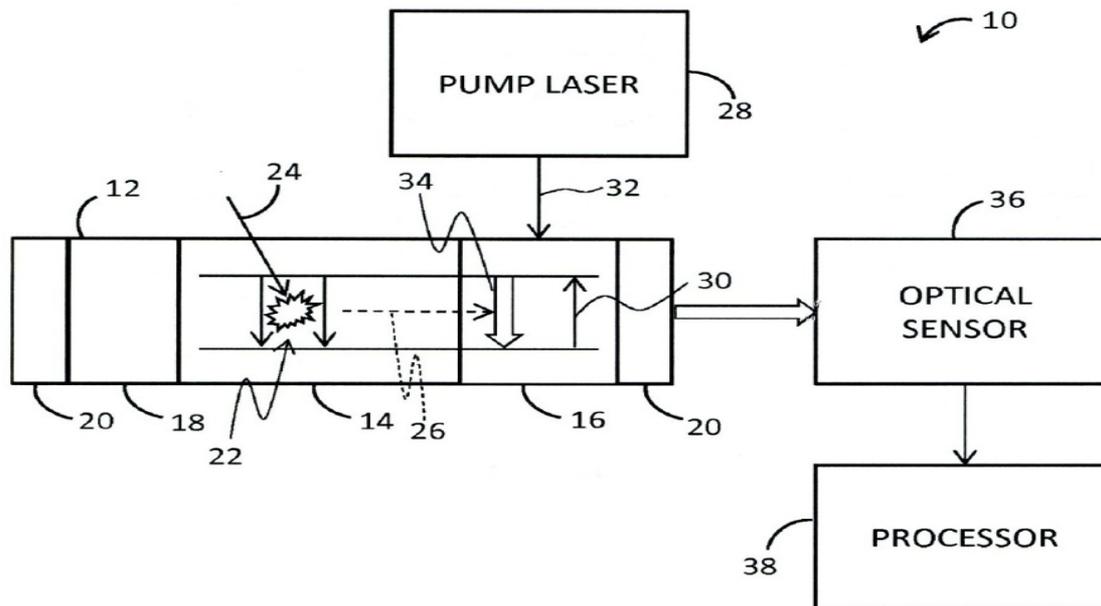
(60) Provisional application No. 61/514,061, filed on Aug. 2, 2011.

Publication Classification

(51) **Int. Cl.**
G01T 1/205 (2006.01)
G01T 1/20 (2006.01)
G01T 1/204 (2006.01)
(52) **U.S. Cl.** **250/366; 250/487.1; 250/361 R**

(57) **ABSTRACT**

A device for detecting ionizing radiation includes a radiation interaction region configured to generate light in response to an interaction with the ionizing radiation, an optical gain medium region in optical communication with the radiation interaction region and configured to amplify the light, and an energy source coupled to the optical gain medium region and configured to maintain a state of population inversion in the optical gain medium region. The optical gain medium region has an emission wavelength that corresponds with a wavelength of the light generated by the radiation interaction region.



Rivelatore Particelle = Sistema a 3 livelli

ρ_{ij} = Densita' Energia EM

B_{ij} = Coeff. Einstein

γ_{ij} = Rate - Transizione Rad + NonRad.

$$\dot{N}_1 = -B_{12}\rho_{12}N_1 + N_2\gamma_{21} + N_3\gamma_{31}$$

$$\dot{N}_2 = B_{12}\rho_{12}N_1 - B_{23}\rho_{23}N_2 + N_3\gamma_{32} - N_2\gamma_{21}$$

$$\dot{N}_3 = B_{23}\rho_{23}N_2 / N_3\gamma_{32} - N_3\gamma_{31}$$

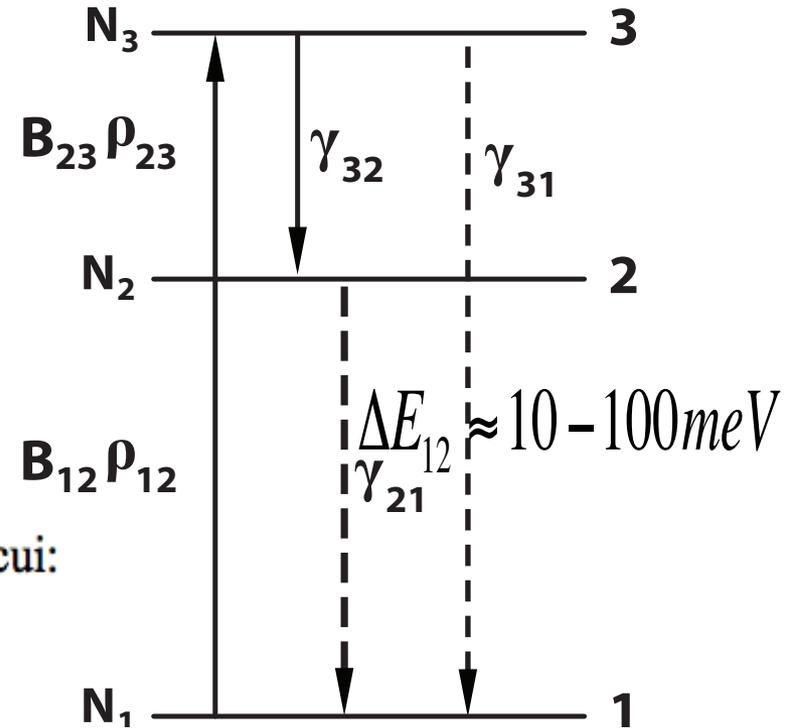
Questa serie di equazioni si può semplificare nel caso in cui:

a) $\Delta E_{21} > kT$ (T cristallo < 4 K)

b) Pompa Laser ν_{23} CONTINUA $\dot{N}_i = 0$

c) V = Volume del cristallo illuminato

d) il cristallo sia poco irraggiato il che significa poca popolazione nel primo stato eccitato



$$R_{31} = \dot{N}_2 B_{23} \rho_{23} T_1 V$$

con T_1 = tempo di rilassamento fononico a 4 K (100 μ s \div msec)

$$B_{23} \rho_{23} = \text{rateo di transizione indotto dal laser di pompa} = \frac{Ac^2 I_\nu}{8\pi h\nu^3} g(\nu - \nu_0)$$

Con

$$A = \text{spontaneous transition rate} = \left(\frac{8\pi^2 e^2 m^2}{\lambda^2 mc} \right) f$$

e f = intensità del dipolo elettrico della transizione pesata sulla funzione d'onda finale ed iniziale.

I_ν = flusso del laser (W/cm²)

$g(\nu - \nu_0)$ = inverso della larghezza di riga

La potenza dei fotoni di fluorescenza prodotti attraverso pompaggio laser è:

$$P_{31} = R_{31} h\nu_{31}$$

L'efficienza quantica di rivelazione su stati eccitati è data da :

$$\eta = \frac{P_{out}}{P_{in}}$$

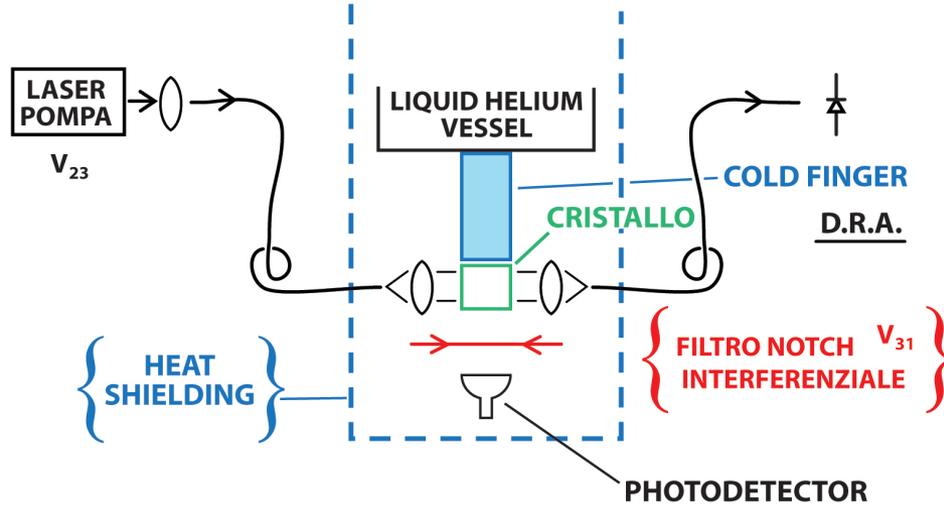
Con P_{in} data dalla potenza istantanea rilasciata sullo stato ΔE_{12} . Questa a sua volta può essere scritta come :

$$\eta = \frac{T_1}{\Delta E_{12}} \frac{\alpha_p \ell_p P_p}{V}$$

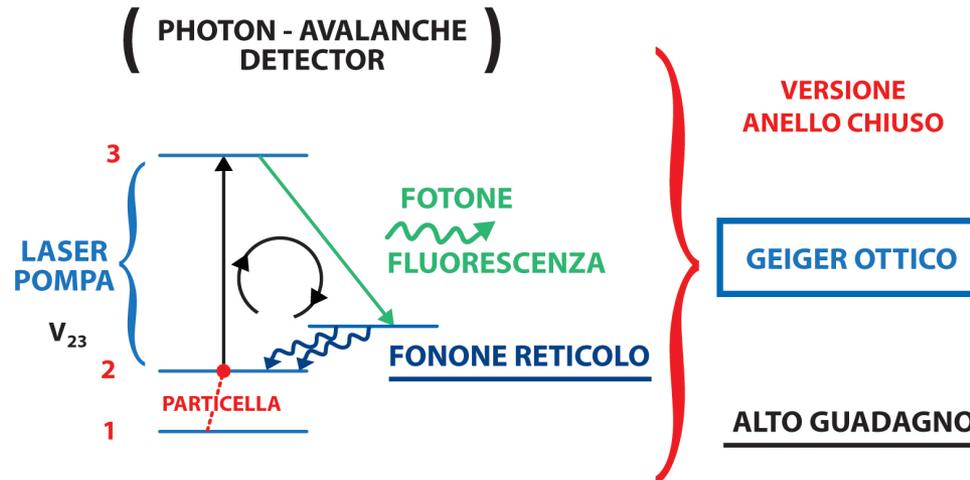
Dove α_p è il coefficiente di assorbimento della pompa laser P_p sugli stati eccitati del cristallo.

Con parametri tipici per cristalli già indagati per gli IR Quantum Counter $P_p = 1$ W/cm²; $T_1 = 100$ μ sec; $\Delta E_{12} = 100$ meV, $V = 1$ cm³; $\ell_p \sim 1$ cm

POSSIBILE SCHEMA SPERIMENTALE



SCHEMI ALTERNATIVI



Piano Ricerca 3 Anni:

Studio Combinato:

Amplificazione Laser su Cristalli e Risposta alle Radiazioni Ionizzanti

Attraverso Emissione di Luce di Fluorescenza

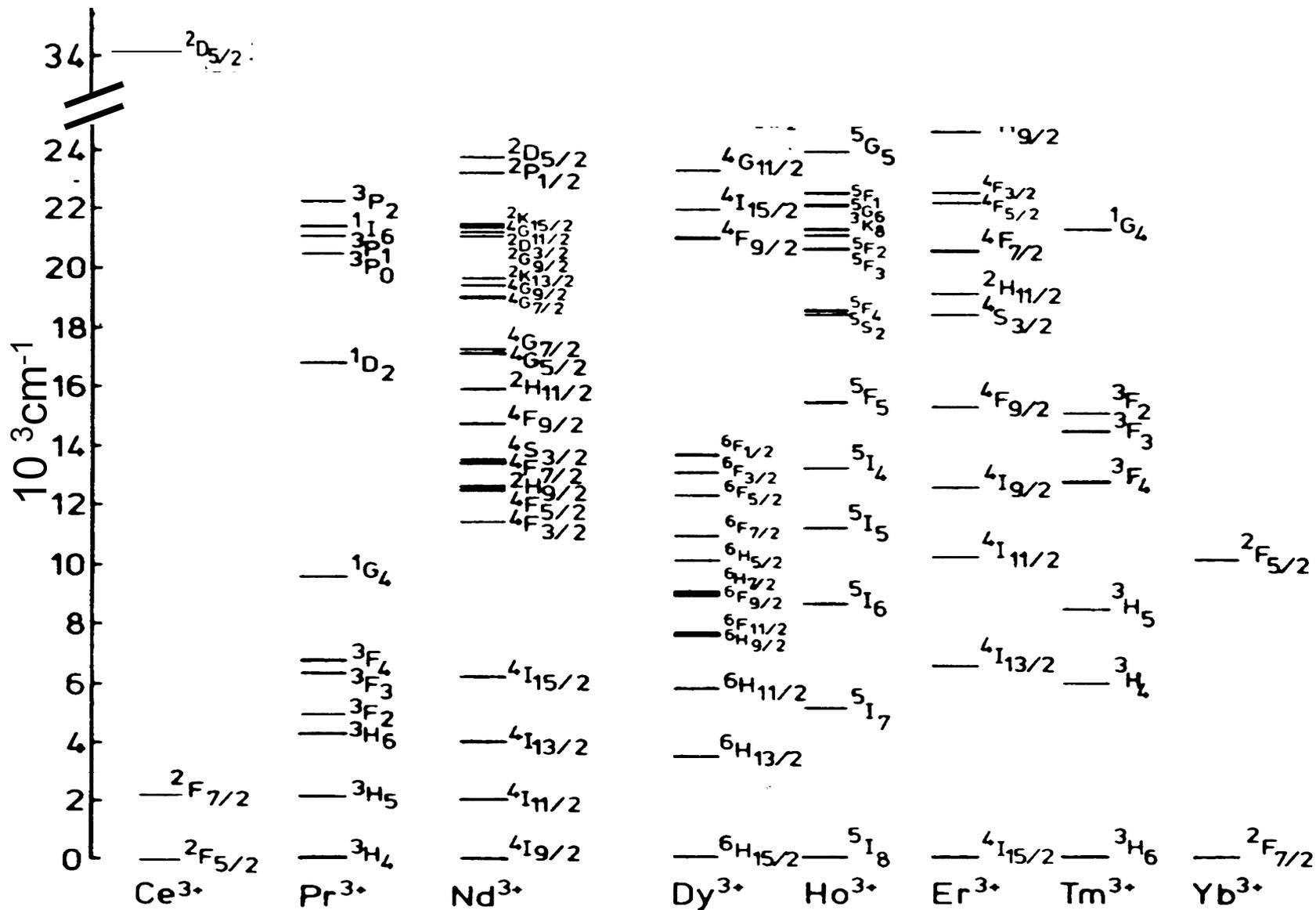
Criostato Liquid Helium + Watt Laser Tunabile + Cristalli + Low Temperature PD

Sezioni : Padova 2,7 FTE, Pisa 1,2 FTE , Cagliari 1,5 FTE

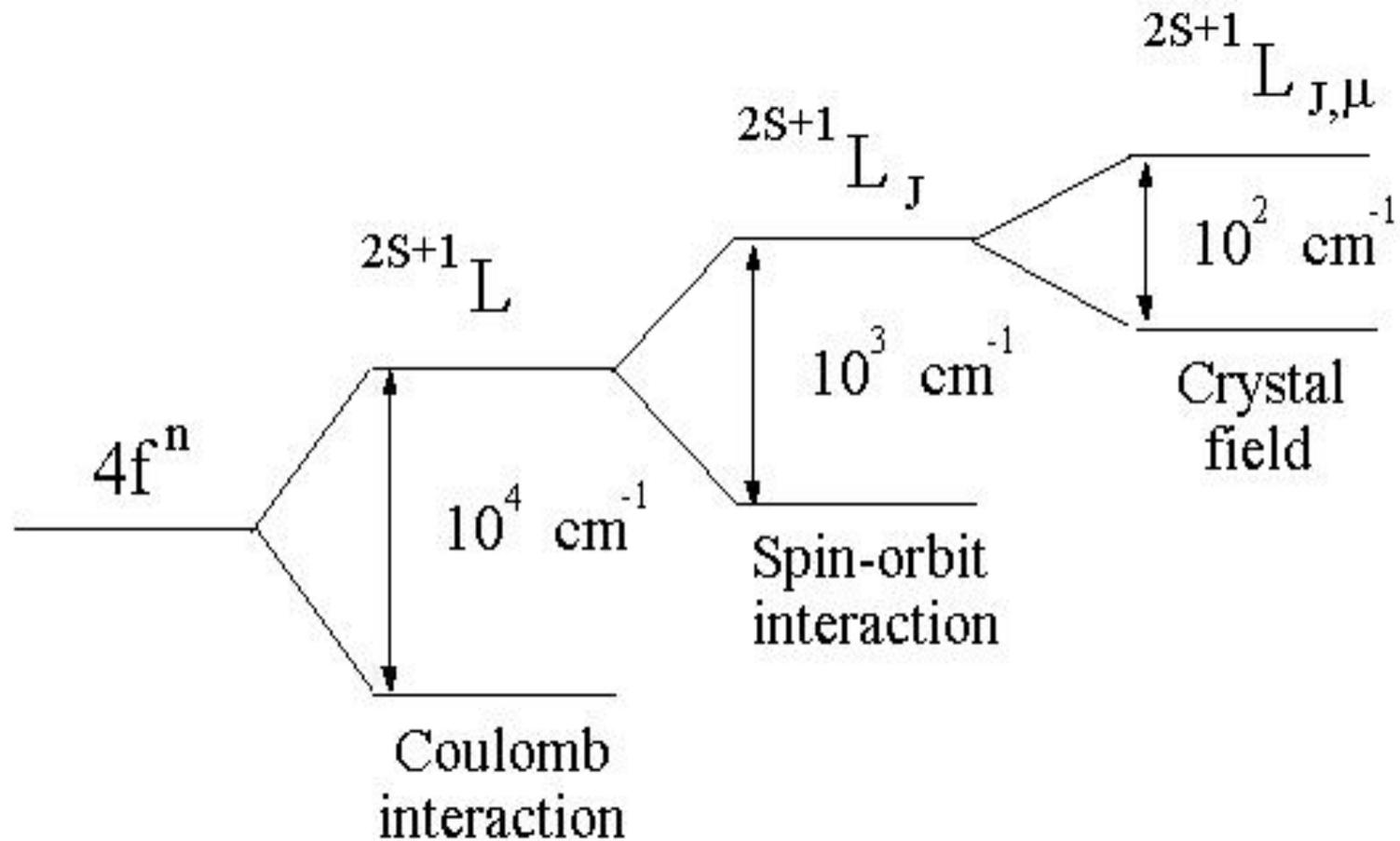
Richieste Finanziarie : 107 KE 2014 , 70 KE 2015 , 60 KE 2016 , Tot. =200 Ke

	40 Keuro (Elio ,Azoto ,Criostato,Laser,Ottica..)	PD
2014	30 Keuro (Elio Liquido ,Elettronica ,Sorgente Crio)	CA
	30 Keuro (Cristalli ,Crogiuoli,.)	PI

Rare earth energy levels



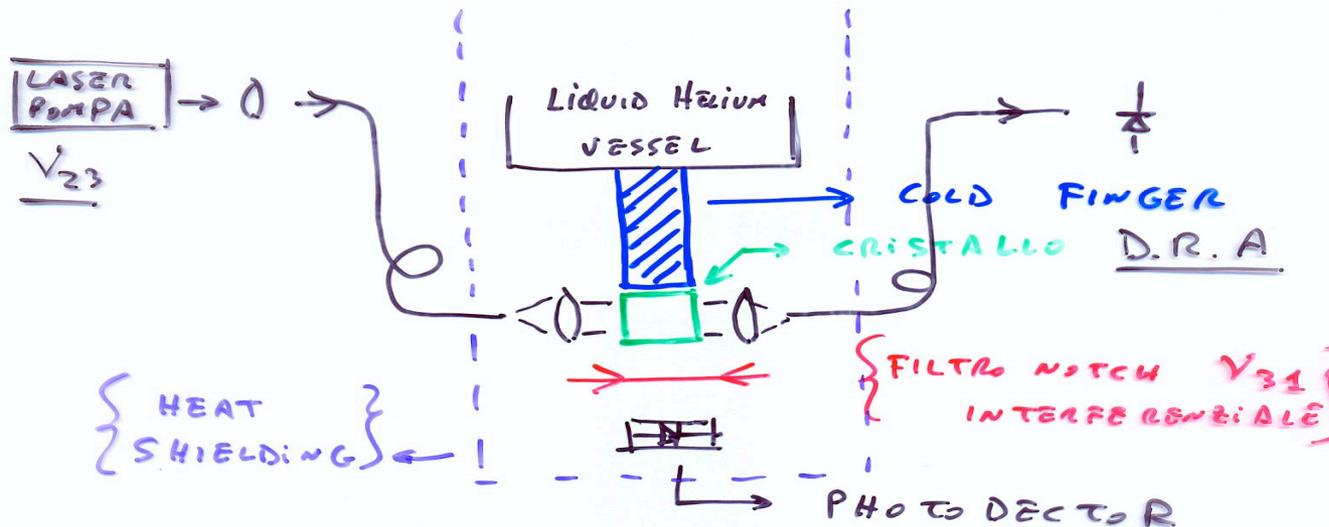
Rare earths in crystals



POSSIBILE

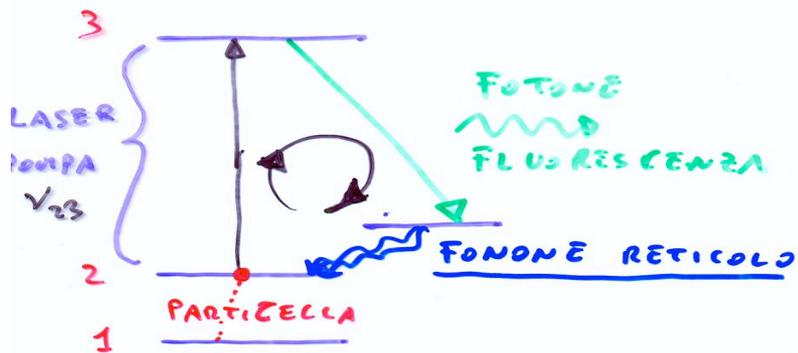
SCHEMA

SPERIMENTALE



SCHEMI ALTERNATIVI

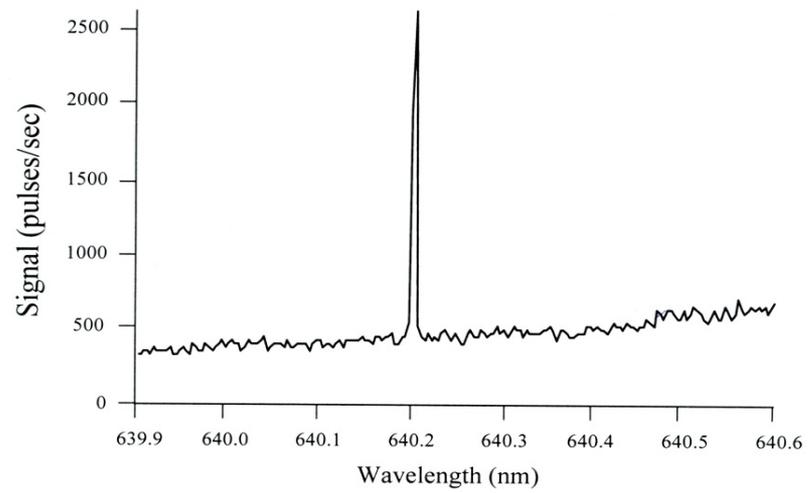
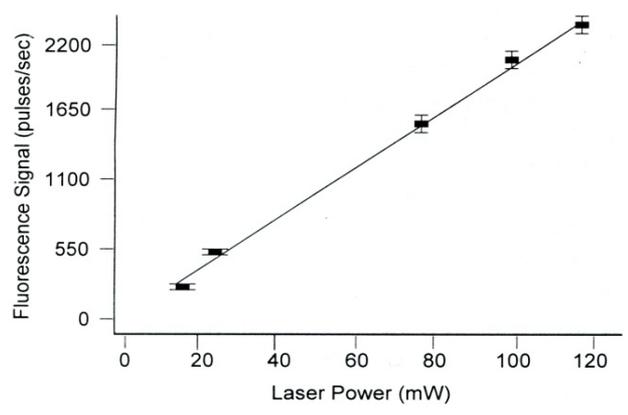
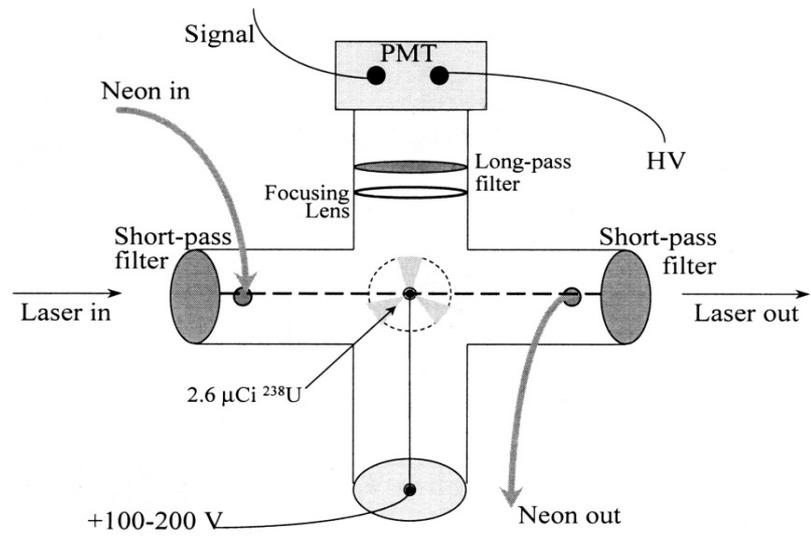
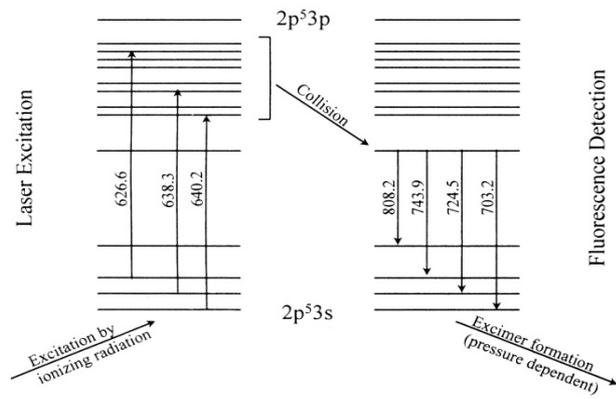
(PHOTON - AVALANCHE DETECTOR)



VERSIONE ANELLO CHIUSO

GEIGER OTTICO

ALTO GUADAGNO



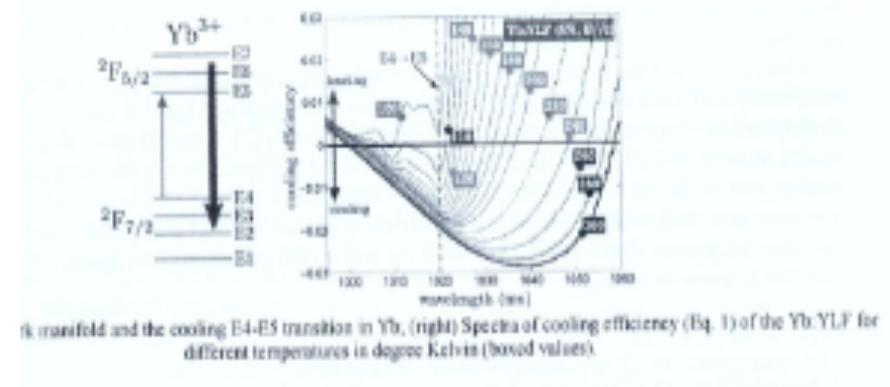
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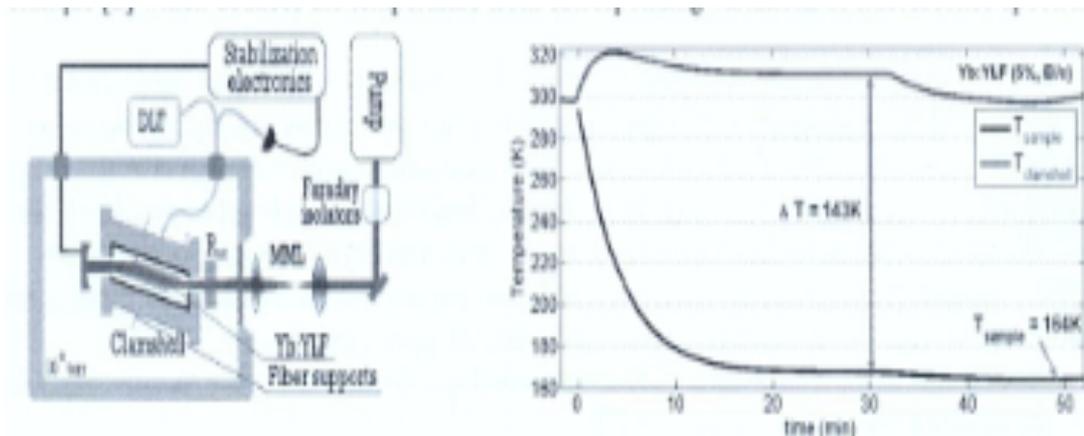
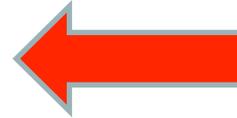


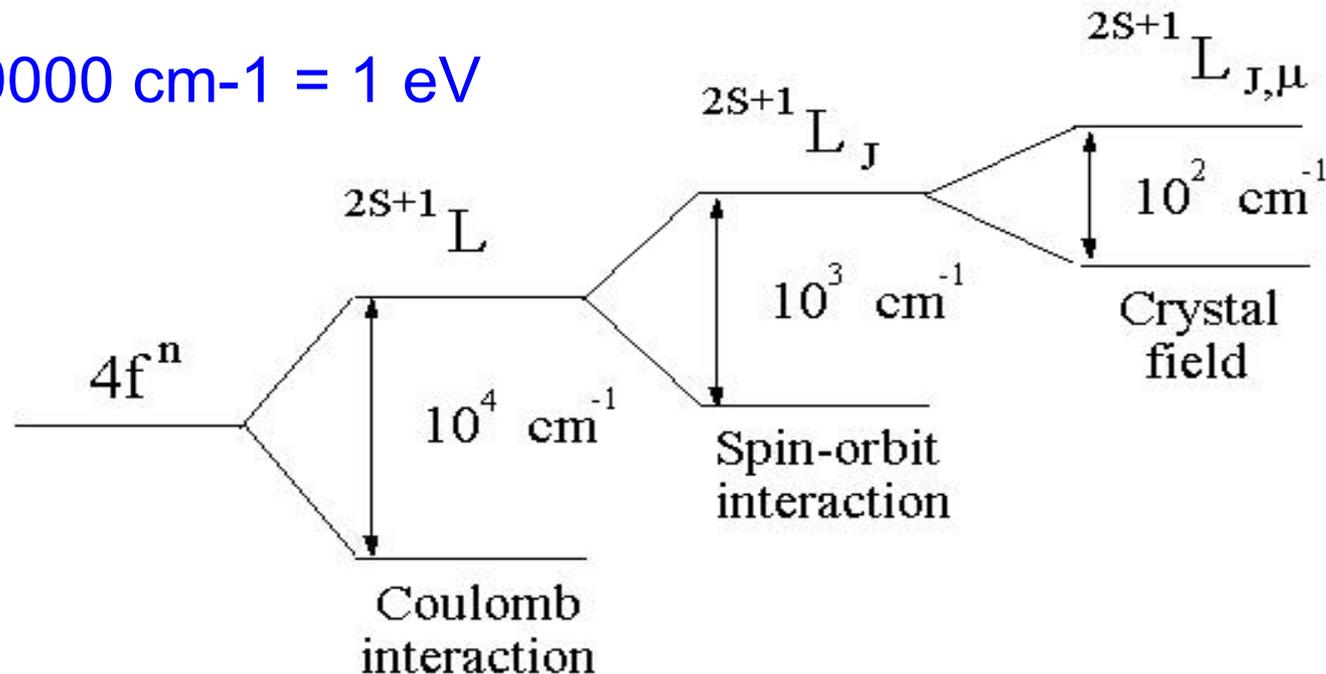
Fig 2: (left) Schematic of experimental setup, (right) Experimental demonstration of feasibility of an optical cryocooler.

Materials Optical Phonon Energy

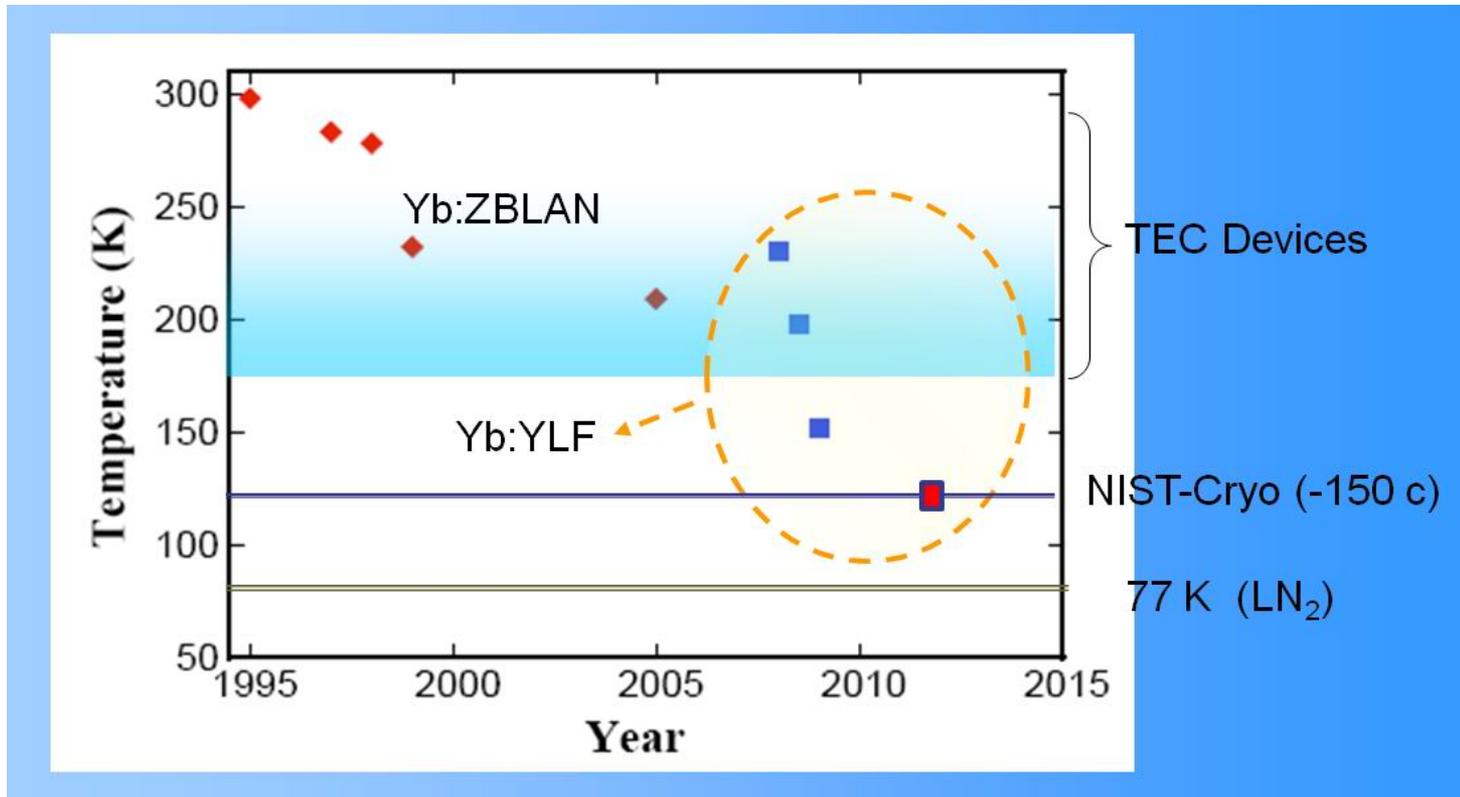
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- Fluoride Crystal: $\sim 400 \text{ cm}^{-1}$
- Chloride Crystal: $\sim 300 \text{ cm}^{-1}$



$10000 \text{ cm}^{-1} = 1 \text{ eV}$



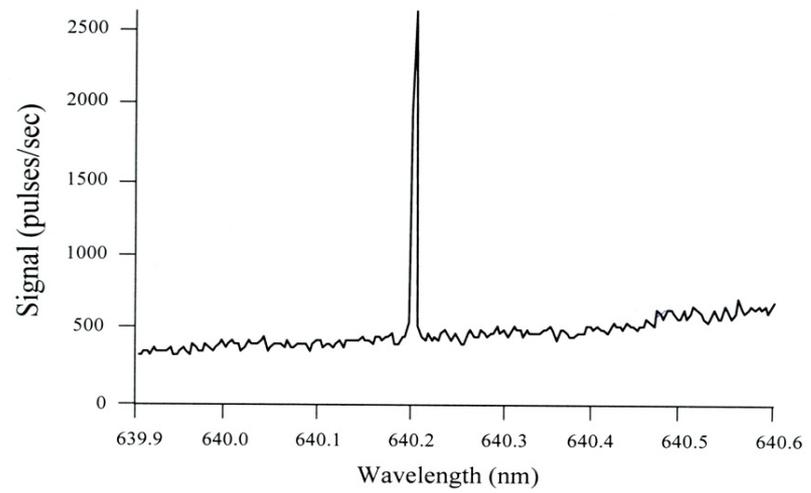
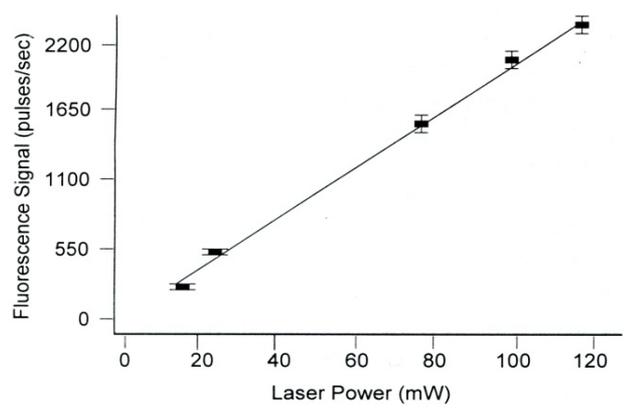
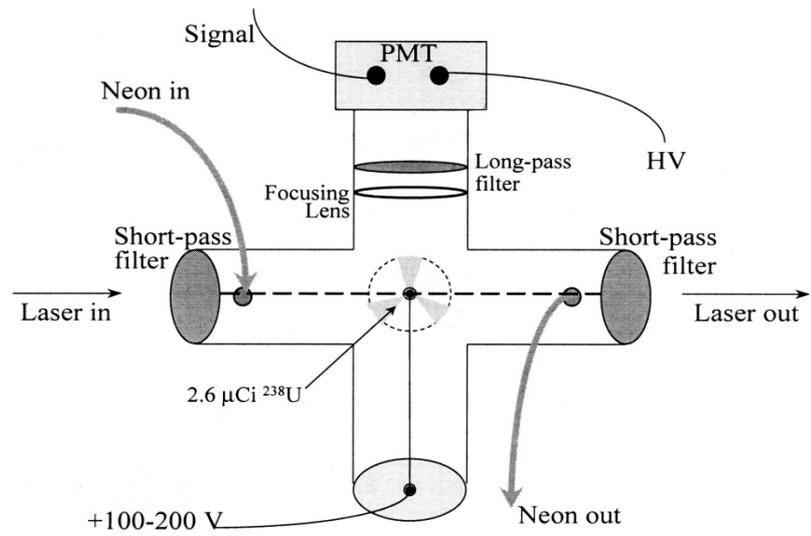
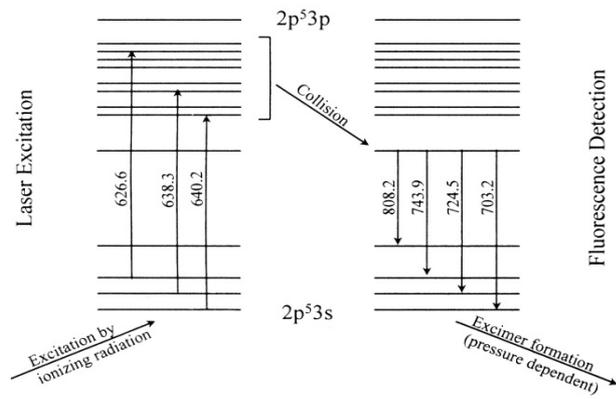
Optical Cooling



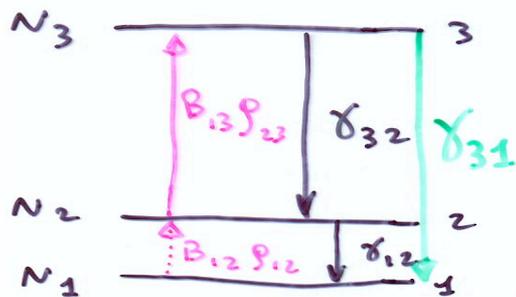
Now the lowest temperature: 119+₋₁ K (~ -154 C)!

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$$\alpha_{\beta} = \sim 10^{-4} \text{ cm}^{-1}$$



RIVELATORE

PARTICELLE \Rightarrow SISTEMA 3 LIVELLI

$$\left\{ \begin{array}{l} \rho_{ij} = \text{DENSITA' ENERGIA E.M.} \\ B_{ij} = \text{COEF. EINSTEIN} \\ \gamma_{ij} = \text{RATE TRANSIZIONE (RAD. + non RAD)} \end{array} \right.$$

\Rightarrow LIVELLO $1 \rightarrow 2$ $\Delta E \approx 50 \div 100 \text{ meV}$
POMPA TO DA dE/dx

$$\left\{ \begin{array}{l} \dot{N}_1 = -B_{12} \rho_{12} N_1 + N_2 \gamma_{21} + N_3 \gamma_{31} \\ \dot{N}_2 = B_{12} \rho_{12} N_1 - B_{23} \rho_{23} N_2 + N_3 \gamma_{32} - N_2 \gamma_{21} \\ \dot{N}_3 = B_{23} \rho_{23} N_2 - N_3 \gamma_{32} - N_3 \gamma_{31} \end{array} \right.$$

$$\# N_i = \text{DENSITA' STATI} = \frac{\text{ATOMI } i}{\text{cm}^3} \#$$

SE : $E_{21} > kT$ ($T \approx 4^{\circ}K$)

+ CONTINUOUS WAVE PUMPING $\dot{N}_i \equiv 0$

$$Rate_{31} = N_3 \gamma_{31} \cdot V = \frac{B_{12} \rho_{12} N_1 \cdot B_{23} \rho_{23} V}{\left(\frac{\gamma_{32}}{\gamma_{31}} + 1\right) \gamma_{21} + B_{23} \rho_{23}}$$

V = Volume \rightarrow (FOTONE FLUORESCENZA)
(FUORI BANDA LASER)

SE WOLTRE :

$$\begin{cases} B_{23} \rho_{23} \ll \gamma_{21} \\ \gamma_{32} \gg \gamma_{31} \\ \gamma_{31} \approx \gamma_{21} \end{cases}$$

$$Rate_{31} \equiv B_{12} \rho_{12} N_1 \cdot B_{23} \cdot \rho_{23} T_1 V$$

($T_1 =$ phonon Relaxation time)

$$P_{OUT} \approx R_{31} \cdot h \nu_{31}$$

DETECTOR

$$P_{out} = R_{31} \cdot h \nu_{31} \quad \left\{ \begin{array}{l} P_{in} = N_{atoms} \text{ su } N_2 \cdot h \nu_{21} \cdot T_1 \\ P_{PUMP} = \rho_{23} \Delta \nu_{23} c A_{RESA} \end{array} \right.$$

P_{in} \propto m^2 atomi eccitati allo stato 2 da PARTICELLA

ASSORBIMENTO DA POMPA LASER su ν_{23}

$$\alpha_{ss. POMPA} = \frac{h \nu_{23} \cdot B_{23} \cdot N_2}{c \Delta \nu_{23}}$$

$$\eta_{efficiente} \equiv \frac{P_{out}}{P_{in}} =$$

$$= \alpha_p \cdot l_{cristallo} \cdot \frac{T_1}{E_{12}} \cdot \frac{P_{POMPA}}{V} \cdot \frac{1}{N_2}$$

$$\underbrace{T_1 \approx \text{msec}; E_{12} \approx 50 \text{ meV}; P \approx W; V = \text{cm}^3}$$

$$N_2 \approx \frac{\text{pochi atomi}^*}{\text{cm}^3} \Rightarrow \left(\eta \approx 100\% \right)$$

Possibilita' di controllare anche gli Spin Nucleari in Sistemi Magnetici

Li7 , F19 ,Be9

Nuclei con + alta Sezione d'urto via Nuclear Excitation via Neutral Current

Targhette Polarizzate Attive possono Fornire Calorimetri Elettromagnetici

Con Campo Magnetico " Built In "

Targhette ad Alta Densita' di Polarizzazione e Tempi di Rilassamento Lunghi

Per Esperimenti Tipo EDM / Assioni / Long Range Spin-Spin Interaction

Miniera Non Esplorata Sperimentalmente